



Citation for published version:

Parry, G & Roehrich, J 2013, 'Automotive enterprise transformation: Build to order as a sustainable and innovative strategy for the automotive industry?', *Journal of Enterprise Transformation*, vol. 3, no. 1, pp. 33-52.
<https://doi.org/10.1080/19488289.2013.784223>

DOI:

[10.1080/19488289.2013.784223](https://doi.org/10.1080/19488289.2013.784223)

Publication date:

2013

Document Version

Peer reviewed version

[Link to publication](#)

University of Bath

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

Take down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Forthcoming in the Journal of Enterprise Transformation (JET)

Glenn C. Parry^a and Jens K. Roehrich^b

^a, Strategy & Operations Management; Bristol Business School; Frenchay Campus, Coldharbour Lane; University of the West of England; Telephone 0117 32 83453 *Corresponding author's e-mail:* glenn.parry@uwe.ac.uk

^b School of Management, University of Bath, Claverton Down, Bath BA2 7AY, UK, Tel.: +44 (0) 1225 385 060; fax +44 (0) 1225 386 473; e-mail: j.roehrich@bath.ac.uk

Automotive Enterprise Transformation: Build to Order as a sustainable and innovative strategy for the automotive industry?

Abstract

The global financial crisis has significantly impacted the automotive industry with reduced supply of credit to industry exposing their process inefficiencies and reduced credit to consumers reducing sales. Firms are restructuring, with some seeking government financial support, but the industry is not addressing the underlying failure of the business model. The transformation of the automotive enterprise is proposed as a potential solution; from the build to stock (BTS) approach currently employed to a build to order (BTO) enterprise in the future. The BTO approach outlined in this paper is drawn from a 4-year study by a European research consortium. The approach developed delivers the triple bottom line of economic, environmental and societal prosperity through addressing wastes such as overproduction, unnecessary transportation and inventory, coupled with innovative modular vehicle design and adoption of integrated supply chains.

Key Words

Enterprise Transformation, Innovation, New Product Development, Build to Order, Lean, Automotive Industry, Supply Chain Management

Introduction

The build to order (BTO) strategy proposed in this paper offers automotive manufacturers an alternative business model which is more sustainable, driving innovative and collaborative solutions encompassing the whole automotive enterprise (Holweg and Pil, 2004). The work seeks to challenge the established build to stock (BTS) business model of the industry and provides an alternative vision of a BTO future. Strategic enterprise transformation is a product of a complex and systemic process (Nightingale, 2009). Political and cultural views of process have an impact upon the desire for change which occurs through a legitimization and delegitimization of ideas (Pettigrew, 2012). In this paper, it is proposed that the BTS business model is no-longer legitimate and the work seeks to demonstrate that BTO has potential as a future approach. While some evidence of enterprise transformation can be found in extant literature (e.g. Ianni, 2011; Rouse, 2011) Rifkin (2011) points out that we need to learn more about enterprise transformation by adopting a systematic approach. To fill this void in the literature, this paper provides a systematic review of the BTO enterprise by providing a deep investigation of the possible future state of the automotive industry.

In order to realize a BTO strategy it is proposed that an enterprise transformation is pivotal in achieving the objectives. Such a transformation calls for radical changes to organizational relationships across key stakeholders, new value propositions for product and service delivery and re-organization of the enterprise (Nightingale, 2009; Purchase et al., 2011). However, the automotive industry is conservative. Since completing a major European project examining the feasibility of the BTO paradigm (Parry and Graves, 2008; Roehrich et al., 2011) the automotive industry has continued

its investigations. An engineering systems approach to manage the transformation has been developed and critiqued by industry (Parry and Roehrich, 2012). Expert's analysis of the BTO approach has suggested that it may be best piloted with further small automotive projects – though this approach has been on-going for a number of years within leading European manufacturers. One manufacturer has internally instigated the successful internal adoption of a BTO approach to the production scheduling of their engine plant. However, this remains a single internal adoption of BTO and the desired enterprise transformation for the European industry has yet to be achieved.

BTO challenges the dominant ideology of the industry and introducing such transformative strategies changes the systems of meaning, structures, priorities and power relationships within the organizing firms – a long and tortuous process (Pettigrew, 2012). A BTO approach would extend through the automotive enterprise, integrating suppliers and providing a much stronger model upon which car companies could rebuild a sustainable automotive businesses (Holweg and Pil, 2004; Roehrich et al., 2011). This will lead to greater dependency between organizations within multi-organization enterprises, thus leading to complexity which needs to be managed to achieve innovation and efficient outcomes (Henshaw et al., 2011). Innovation in product and supply chain structure lies at the heart of the BTO vision. Through careful design and extensive utilization of modularity it is possible to provide a high number of product variants to the market, configure the final product much later in the process, whilst limiting the number of different component parts required (Parry and Graves, 2008). Achieving this requires supply chain innovation and integration which builds upon previous lean implementations, facilitating the smooth flow of data that controls the build activity.

This paper provides a view of the possible future BTO process which will deliver the vision originally promised by Lean production, building cars at the rate of customer demand. The paper proceeds through the following parts: (i) What is Build to Order?; (ii) Drivers of Transformation; (iii) The Intelligent Logistics for Innovative Product technologies (ILIPT) project; and (iv) The three ILIPT program components (1) Modular product development; (2) Supply chain innovation; and (3) Validation and implementation of a BTO strategy.

What is Build to Order?

Build to order refers to a demand-driven production approach where a product is scheduled and built in response to a confirmed order received for it from a final customer (Holweg and Pil, 2004; Parry and Graves, 2008). The final customer is a known individual purchaser. This definition excludes all orders by national sales companies (NSC), car dealers, fleet orders or other supply chain intermediaries (Parry and Graves, 2008). Also excluded is the order amendment function, whereby vehicles in production are amended to customer requirements, as this is seen as another level of sophistication for a BTS system (Parry and Graves, 2008). In contrast to BTO, in the current dominant BTS systems of the automotive industry products are produced before a final purchaser has been identified, with production volume driven by forecasts (Roehrich et al., 2011). High stock levels allow some dealers to find a match to the purchaser's desired vehicle, but is expensive and inefficient as finished goods are rarely located where they are required (Parry and Graves, 2008).

BTO systems do not require all suppliers in a network to produce at the rate of final customer demand. A manufacturer of sparkplugs, for instance, should adopt a BTS strategy, whilst manufacturers of larger and more expensive components such as an engine should adopt a BTO strategy. The extant challenge for supply chain managers in a BTO network is the identification and management of the BTO to BTS boundary. This point in the supply chain is named the 'decoupling point'. At the moment most automobile production supply chains lack a decoupling point, resulting in high stock levels. Development of innovative BTO products and processes requires a significant investment in research and broad access to expert resources.

Drivers of Enterprise Transformation

Competitive advantage is afforded to those companies who can provide a product at the right price and quality and provide this to customers within the shortest lead time (Bower and Hout, 1988; Stalk, 1988). Evidence indicates that automotive companies have inefficient processes with regards to providing their customers with the vehicle they desire within a short timescale and to overcome this

the companies hold stock worth billions of dollars. Before the financial crisis the stock figures reported in the US averaged 25 days for BMW, 35 days for Toyota and 85 days for GM (Automotive News, 2006/7). Despite the volume of stock holding the variety offered by the original equipment manufacturers (OEMs) meant customers frequently did not receive exactly what they desired but, incentivized by manufacturer discounts, they purchased a compromise vehicle whilst manufacturers eroded their own profits (Holweg and Pil, 2001).

An on-going financial crisis in the west has impacted credit availability for both automotive companies and customers, creating a decline in customer orders in many major markets. The fiscal constraint brings a focus upon the finances of automotive companies (Crumley, 2012). Companies' weaknesses such as overcapacity and rising stocks have been even further emphasized through the financial crisis. The return on capital employed (ROCE %) and change over the past five years for the leading global automotive firms is shown in table 1. The figures must be treated with caution as the larger groups have significant interests beyond auto sales, including finance and property. However, in overview the numbers show that the automotive industry has been through a challenging period and the erratic changes in ROCE makes future performance difficult to forecast. This constrains investment and costs of capital are increased due to the risk associated with the sector's apparent instability.

Please insert 'Table 1' about here

Losses made by the automotive firms have to be financed and companies have significant pension liabilities. US manufacturer Chrysler took bankruptcy protection in 2009 and was supported by the US treasury until Fiat of Italy took a controlling interest (Watson, 2009). In contrast, established Swedish car manufacturer Saab Automobile AB received financial guarantees from their government but their plants closed and the firm was filed as bankrupt in Sweden in December 2011. The French manufacturer Peugeot had to negotiate \$9 billion in guarantees from the French Government in mid-2012 to ensure it could continue trading (Rosemain, 2012). The findings show the impact of the financial crisis has led to a significant number of job losses across the supply chain (Sanchez-Ramirez et al., 2011). Evidence indicates that the BTS business model exposes suppliers to heightened

financial risk when investing in tooling and stock as a result of the potentially inaccurate and overly optimistic OEM sales forecasts (Holweg and Pil, 2001; Hofman 2011). The financial risks taken by smaller supplier firms extends to the OEMs as failures in a supply network have an impact upwards and can lead to multiple failures (Cossin and Schellhorn, 2007).

The financial crisis of 2008 crippled sales and a lack of availability of capital stilted cash flows, causing automotive stocks to increase rapidly at a time when it was least affordable. Reported US stock figures for December 2008 showed significant stock increases with an average of 44 days for BMW, 90 days for Toyota and 139 days for GM (Automotive News, 2008/9). The evidence shows that companies almost doubled stock levels during the worst of the downturn, and there is a suggestion that there is an endemic under-reporting of figures by the industry (Webster, 2006). Similarly, reported sales for February 2008 and 2009 showed a fall of 41.3% for major US manufacturers, leading analysts to declare an 'automotive recession' (Thompson, 2009). This has potential to cause great damage to the automotive companies as it highlights their inefficiencies. It is proposed that increased liquidity may be achieved through inventory reduction (Hofman, 2011). To reduce inventory the reaction of the vehicle OEMs was to halt production, with Honda shutting its' UK base for four months (BBC, 2009) and Toyota halting Japanese production for two months (Ryall, 2009). Governments around the world backed packages such as the 'cash for clunkers' or 'scrappage schemes' seen in Europe and the USA. This has helped the industry to turn some of its' capital tied up in stock back into cash and perhaps saved the industry in the short term. For example, automobile sales in Germany were reported to have risen 40% as a result of these schemes, but shares in automotive OEMs fell as investors were unconvinced that the governments rescue measures created sustainable change (Reuters, 2009).

Financial stress may facilitate the full adoption of a BTO strategy as financial crises have precedence as a driver for change in the automotive industry. The Toyota Production System was created through necessity following the Second World War when Japanese companies could not raise the capital necessary to build automobiles using the mass production processes developed in the US (Ohno,

1988). The automotive industry has a history of recovery from crisis through adoption of leading innovative practices in product design and manufacture (Holweg, 2008). For instance, lean was a result of necessary innovation in vehicle production, minimizing waste and hence cost. Contrasting the approach of mass production developed by Henry Ford and providing a challenge to manufacturing convention, central to Ohno's vision was the building of vehicles at the rate and variety demanded by the customer – building to customer order – such that each vehicle was paid for before it was built (Monden, 1983). Japanese best practice in automotive manufacturing, named 'Lean production', was studied during the late 1980s to the early 1990s as the automotive industry in the West sought to close the significant productivity gap which had developed (Womack et al., 1990). As evidence shows, the productivity gap between Western and Japanese manufacturers, initially identified by Womack et al., was substantially reduced by rigorous application of lean thinking (Merlis et al., 2001). To broaden the focus of Lean Ianni (2011) outlines the steps needed to successfully realize Lean enterprise transformation in an automotive company. Roth (2011) further outlines key factors to realize Lean transformation, though it is noted that the automotive industry has not delivered on the original Lean promise of manufacturing to customer orders (Stone et al., 2006). Ample evidence has been found for current and future improvements in manufacturing efficiency delivered through factory focused Lean implementations, but not improvements in profitability.

Whilst previous research has shown the efficiency of the mass-production business model was improved by Lean practices a number of flaws such as overcapacity and variation in demand were made more obvious by the financial crisis. The leading practices of the industry enables a car to be built from flat steel within 11 hours, however, customers placing their order at the dealership have to wait at least 40 days for delivery of their vehicle or they can chose to buy one immediately from stock (3DayCar, 1999-2001; Holweg and Miemczyk, 2002 & 2003; Miemczyk and Holweg, 2004; Parry and Graves, 2008). It is proposed that the business model is self-defeating and the automotive industry has created grounds for their own failure through their vehicle product model cycle, described in four phases (Holweg and Pil, 2001):

1. Develop new vehicle; lower target costs set by OEM. Achieving target costs demands an increase in sales volumes. Optimistic forecasting of future sales facilitates the vehicles development path to production.
2. Launch new vehicle; temporary profit? However, forecast volumes are optimistic and set above demand to justify the high cost of investment.
3. Vehicle in market; factory capacity demands that high production volumes are maintained even though sales are not meeting the volume targets set. The OEM introduces pressures and incentives to increase sales, achieved through discounting, fleet sales and pre-registration of vehicles to place them directly into 2nd hand market.
4. Price environment worsens; all competitors are employing the same business model. To make the vehicles more attractive to buyers the OEMs increase the specification of vehicles in each market segment, but the segment price is permanently driven down.

The evidence suggests that the automotive industry clockspeed, (Fine, 1999) does not match the expectation for instant gratification its' marketing departments have created within the customer base (Parasuraman et al., 1985). Clockspeed may be seen as a measure of the rate of business evolution, or how quickly a company can convert investment in innovation into cash through mastery of their product, process and supply chain. The nature of product and lifecycle are determinants of a successful supplier strategy (Fisker, 1997). For instance, Dell Computers are well positioned to provide quick response to customer variety by holding stocks of final components and configuring them to customer's purchase order. However, due to the variety of components utilized in an automobile research suggests a 'late configuration' strategy is infeasible due to the investment in capital holding required (Holweg, 2005; Scavarda et al., 2009). Manufacturers are still faced with the challenge of creating a responsive enterprise that quickly addresses customer demand without holding large stocks (Roehrich et al., 2011).

The European Commission recognized the sustainability of the BTO model and the importance of the automotive sector within Europe. The prohibitively high risk and cost associated with research and

development of an innovative BTO enterprise approach to manufacture was too great for a single company to bear, so the EU Commission, in partnership with industry, provided \$23 million to fund a cross-country research study – the ILIPT project.

The ILIPT Project

The European Commission, through its four year ‘Intelligent Logistics for Innovative Product Technologies’ (ILIPT) program, colloquially known as the ‘5-day Car project’, proposed a pan-European research project to study the applicability of BTO across the European automotive sector (see Parry and Graves, 2008 for a detailed explanation). The ILIPT project developed from preliminary work undertaken based upon UK manufacture and delivery, the 3DayCar project (3DayCar, 1999-2001). The 3DayCar project had established a consensus from both dealers and customers that an acceptable order to delivery time is between 7 and 14 days (Williams and Waller, 2000; Waller, 2001). Further, building to order would end the confrontational and bargaining nature of car sales driven by the BTS business model and would necessitate a shift in behavior in both supplier and customer to jointly fulfill customer needs. When moving from a UK to the geographically larger European context the research aimed to realize a target vehicle delivery period of five days from order to delivery. To meet this target, the research called for radical improvements in productivity and changes in technological capacity. The ILIPT project aimed to help support and facilitate the delivery of this approach through a set of innovations:

- Management of product configuration for flexibility: addressing the need for a global product with local configurations in systems and modules for cars to 2015 which will lead to novel approaches to customization of cars and their subsystems
- Innovative production, supply and logistics networks: groundbreaking informational and material flow processes and software prototypes for designing and evaluating production networks that model new approaches to customization, fulfillment and logistics.

- Management of information flow: defines the critical path for information flows during build to order through sophisticated electronic applications to facilitate a seamless knowledge and information flow.
- Management of material flow: radical change in the management of supplies, inventories and the packing, transportation and monitoring of parts, modules and cars towards a customer-specific treatment and optimization.
- Extended automotive enterprise: where the whole supply chain operates on consumer demand, in real-time, with no stocks through collaborative planning and execution models providing pre-normative measures for future requirements on inter-enterprise integration standardization.

To achieve this vision an automotive consortium was created, drawing on experts from industry and academia. Partners were engaged from Europe, Russia and Brazil. Original Equipment Manufacturers (OEMs) and Tier One suppliers representing the complete supply chain were brought together including Daimler, BMW, Lear Automotive, Dana Corporation, ThyssenKrupp Steel, Siemens VDO, Saint Gobain Sekurit and the European Association representing automotive suppliers - CLEPA.

The ILIPT project represented the European effort to develop new concepts and this paper continues with an overview of the key research outputs which illustrate how a BTO vision may be achieved, focused upon the innovative elements that will deliver a globally leading automotive industry. Greater detail of the whole project may be found within the book produced by the project participants (Parry and Graves, 2008). The ILIPT project was split into three core areas. The first, named ModCar explored the need to change product design and configuration for greater flexibility, supporting the principles of the ILIPT project. The second area developed processes for more flexible supplier networks and the third area produced models to test and validate the integrated processes, drawing upon actual data including sales, order lead times and transport times provided by industry. Each will be discussed in greater detail in the following sections.

Modular product development

Automotive OEMs seek to provide products that address the needs of as many customers as possible, thus providing market coverage. Evidence indicates that the visual, external differences between vehicles play a significant part of defining their market segment. Internal differences such as fuel injectors or window motors are less significant and common parts with modules are shared across vehicles. Research showed that manufacturers seek to minimize their product part variance, which drives up cost, and maximize part commonality whilst maintaining individual product integrity and segment differentiation within the market (Gneiting and Sommer-Dittrich, 2008). Modular architectures provide a possible solution to this challenge, dividing a product into partial systems or modules which ideally connect through common standard interfaces. Each module consists of a number of sub-modules, creating a hierarchy. Product variants can be created by changing different modules and this set of interchangeable modules creates the product family.

Evidence indicates that this approach has already been employed extensively in automotive product design where significant focus has been placed upon common platform strategies (Untiedt, 2008). Many common parts, including much of the main chassis, are reused over different vehicle variants. This allows higher volumes to be produced and delivers lower costs, though high volume processes require higher capital investment in tooling. However, the majority of OEMs current body architectures are monocoque based, with styling surfaces forming part of the load bearing structures. To produce variation in the appearance of the body different panels are used across common platforms which can frequently only be assigned to one product variant, increasing variant number and cost. Despite the efforts of lean theorists (e.g. Womack and Jones, 1995), evidence shows that in practice most manufacturers' body panel metal presses take a long time to change dies between different variants, leading OEMs to favor manufacturing large batches. When common body parts are used color remains a major variant which adds to the complexity and cost as parts must be correctly sequenced to arrive on the final assembly line (Schaffer and Schleich, 2008). Paint shops are often

unreliable and challenged with color matching across different base materials e.g. plastic, alloys, steel grades and galvanized coatings, using different paint types of the 'same' color (Untiedt, 2008).

Within the project leading practice from within the automotive industry was utilized to develop a flexible product strategy based on maximizing modularity. A virtual car, named ModCar, was designed and prototyped for production. The ModCar had to conform to industry requirements for vehicle structure which included stiffness and crash protection. All features and variants had to meet packaging requirements to ensure the standard equipment found in a modern automobile could fit within the body structures. Three core aims guided the decisions made for the body design: a reduction in production time; a simplification of the order and delivery network facilitating logistics; and a reduction in the required fixed capital within the whole process (Parry and Graves, 2008).

Building on research done by Daimler AG (Truckenbrodt, 2001; Elbl-Weiser, 2003) it was decided to develop the vehicle with the body structure separated from its styling surfaces. The concept based on a modular structure with decentralized production provides a route for inexpensive development and production of vehicles. The approach allows smaller localized production units to build the final vehicles, removing the need for significant investments in factories normally associated with car manufacture. The separation of body and styling surface has previously been used for a low volume commercially available vehicle, the BMW Z1, built between March 1989 and June 1991 (BMW.com). Through modularity and a focus on commonality the Z1 shared many of its parts with the higher volume BMW 3 Series E30 model. It removed the paint line from the main vehicle production process which saved time and cost. Clip on styling surfaces are attached to the body to complete the car.

Adopting this approach, the structure of the ModCar body is built from parts that are simple in shape and easy to manufacture. Individual parts were reused in as many different body modules as possible. Materials were chosen to best suit the performance requirements of that body part, in relation to weight, crash worthiness and stiffness. The body structure followed an approach which had been developed by Daimler AG known as "quartering the car". This approach deconstructs the vehicle into

a set of four modules: a front module; engine module; greenhouse front and greenhouse rear. By following this approach eight different modules could be combined to produce four different vehicle variants: a five-door, three-door, estate/wagon and convertible, as shown in Exhibit 1. The front end and engine module are common to all body variants. The greenhouse front for the five-door and wagon is a common element. The difference between the three and five-door variants is the positioning of the B-pillar on the module, which allows for greater commonality of sub-components (Untiedt, 2008). The convertible front greenhouse has a number of differences due to the requirements for increased vehicle stiffness and roll-over protection strength of the A-pillar resulting from removing the roof. All parts below the spring/suspension mounts at the rear of the vehicle are common to all, though additional reinforcements are in place for the convertible. The rear consists of three modules: a module that is used for both the three-door and five-door variant; a module for the wagon; and a module for the convertible (Untiedt, 2008). Both front and rear modules are fitted with crash boxes which help to limit damage and lower the cost to repair the vehicle should it be involved in a low speed crash (Untiedt, 2008). The modules are further split into sub-components which enable a high packing density for transportation. The combination of modules is shown in Exhibit 1, which includes the percentage commonality achieved for each variant.

< PLEASE INSERT 'Figure 1. Illustration of commonality between variants 'ABOUT HERE >

As it can be seen from Exhibit 1, it is possible to have extensive commonality between the variants, with the convertible, at 30%, having the greatest number of unique parts. The implied cost reduction in areas such as complexity, handling, and storage is significant (Schaffer and Schleich, 2008).

To facilitate late determination of a product variant within the supply chain the modules are only joined together after they are equipped with components and interior materials (Untiedt, 2008). This limits the module joining techniques available to cold-joining technologies. Common interfaces were required; all oriented longitudinally to the vehicle direction of travel to ensure a feasible joining process that supports the crash worthiness and stiffness performance requirements (Untiedt, 2008). The most suitable cold joining technique identified was an adhesive used with an additional mechanical screw bond. This technique of combining mechanical and chemical bonding has been

used commercially for the chassis of the Lotus Elise (Lotuscars.com). The Lotus Elise has been in production since 1996 and, in a more developed form, the Lotus modular chassis platform is used for the Evora which began production in 2008.

The outer styling surfaces for the ModCar would also follow the proposed ethos of modularity, low complexity and commonality. The commercial viability of the ModCar meant that, as well as technical viability, it also has to be styled so that it appeals to the tastes of the European market. The modular body shell proposed consists of different outer panels and structures which, whilst not designed to bear the substantial mechanical loads of monocoque chassis, still had to meet legislative requirements for crash and impact protection, as well as lighter wind loads and general misuse encountered in regular driving (Gude and Hufenback, 2008). Body frame commonality meant that significant commonality could be carried over into the styling surfaces. Careful design was required to ensure that reuse of modules across variants did not impact upon the aesthetics of the vehicle. The front module was kept the same in all derivatives. The five-door and wagon variants only differ with regards to the design of the rear panels, with the side panels being common (Gude and Hufenback, 2008). The resultant designs are shown in Exhibit 2.

< PLEASE INSERT 'Figure 2. Styling variants of the ModCar' ABOUT HERE >

In addition to the commonality, the design of the body panels allows for high packing density when in storage, following the project ideology and further reducing cost (Gude and Hufenback, 2008). To eliminate the need for a paint shop, for complexity, cost, and environmental reasons, the panels are manufactured from pre-colored thermo formed injection molded plastic.

To join the outer panels to the body frame multi-functional connector elements were developed. These are bridging structures that snap on or screwed onto the body frame and connect to the styling surfaces using adhesive bonding, which provides high variation tolerance at the join. Connecting methods such as mounting pins or holes for body frame and shell would have added to the complexity and hence cost. The potential complexities include localized increases in material thickness to provide strength, compensation for thermal expansion and the challenge of accurately mating parts across

variants. The modular product innovations described all support the concepts of BTO but require a collaborative and integrated supply chain so that they can be brought together as demanded.

Supply chain innovation

Research evidence indicated that to deliver the 5-day car improvement in the flexibility and integration of the supply chain across physical, information, data, planning, and control processes is required. The industry project partners agreed that modularization of the product requires extensive collaboration within the automotive enterprise such that the modules of the car are co-developed between parties, reducing interface constraints ensuring information is shared and deliveries are made on time. The approach introduces dependencies between firms which require increased collaboration (Howard and Squire, 2007).

The dependencies mean a shared vision of the 5-day Car approach is required across the automotive enterprise: stocks must be avoided, order to delivery times reduced, queries answered rapidly and planning order data shared rapidly. These elements reflect the Lean principles (Womack and Jones, 1996; Henderson and Larco, 2000; Liker, 2004). Evidence shows that to achieve this goal collaboration in the planning process is required. Collaborative planning requires the production demand volumes are distributed across the available final assembly plants according to the build capacity available and the plants proximity to the final customer. The research found that in order to achieve collaborative planning OEMs need real-time data, providing the actual available and utilized production capacity of their suppliers. Though commercially sensitive, this data is required to allow OEMs to dynamically assign customer orders with detail of specification, delivery time and location, such that suppliers can send their outputs to the build lines in sequence with the production process. Utilizing local knowledge, local planning is undertaken by each plant to optimize the productivity of their internal processes. Collaborative planning is undertaken at a higher level of analysis of suppliers and OEMs as allocation of demand for vehicle manufacture is optimized for the flows through the production capacity of the networked enterprise. Planning autonomy must remain with production partners to protect their commercial independence, but virtual order banks and autonomous agent

negotiation is used for rapid assignment of orders to suppliers. Pre-negotiation of a supplier's available production capacity maximum and minimum levels, or 'bandwidth', along with conditions for temporarily extending or reducing capacity, such as cost and times, allows for an automated collaborative process. Demand violations of the capacity limits would imply that the collaborative plan has caused a breach in a pre-agreed capacity limit with a supplier. The automated process then seeks to redress any capacity violation. The virtual order bank identifies plants that contribute to the violation and analyses the situation within the context of the violation. Excess capacity may be re-directed to a plant with spare capacity. If this is not available an 'additional capacity agreement' is initiated where capacity may be added [or lowered] within a pre-agreed restricted scope and timescale. Such a process ensures that the networked enterprise of collaborators remains viable, is sensitive to the commercial interests of each party and further negates contractual arguments when 'rush jobs' are encountered. The current approach requires individuals at OEMs to contact suppliers individually to negotiate separate contract amendments. The autonomous process is able to act more quickly and has been shown to be achievable using current IT systems, linked through innovative supporting systems (Fischer et al., 2008).

Validation and implementation of BTO strategy

The dynamic BTO process described is able to create and utilize a significant number of different possible supply chain routes, flowing parts through the value network (Parolini, 1999). The dynamic design of value networks considers: logistics strategy, supplier selection, relationships and location. Supply chain design determines suitable conditions for planning and execution and ensures that the chosen pathways are economically efficient and viable in terms of the order, production and delivery of a bespoke vehicle to the customer within five days (Person and Olhager, 2002; Chopra and Meindl, 2009). Static comparative analysis and dynamic simulation are used extensively by automotive supply chain analysts. Static comparative analysis is a simple analysis which can be undertaken rapidly. Dynamic analysis is more time consuming but provides much greater granularity of data. The dynamic data-flow simulation models are particularly useful in identifying constraints or bottlenecks within processes. Research undertaken as part of the project found that a combination of both static

and dynamic techniques provides a feasible approach to analyzing large numbers of supply scenarios: static modeling is used to identify the potentially valid processes from the large number of possible permutations; and dynamic modeling simulates and identifies the optimal solutions.

The validity of the holistic BTO approach was tested by simulating and modeling the supply network. This was done using real demand data from industry based upon a commercially available vehicle in production which had the same variants as the ModCar, with timeframes set in the year 2015 (Ost and Mandel, 2008). To model the approach a set of assumptions based on actual conditions within the European automotive industry were used which included: 15 OEM plants were established across Europe to build the vehicles; BTO and BTS suppliers were identified which were situated such that their locations meant they could deliver the product varieties; a virtual order bank and information transparency had been implemented successfully across the enterprise (Toth et al., 2008).

< PLEASE INSERT 'Figure 3. Analysis of Build to Order methodology' ABOUT HERE >

The analysis, Exhibit 3, showed that following the proposed ILIPT BTO strategy an OEM could deliver 50% of vehicles within the five day target time. 97% could be achieved within six days and 100% within eight days. Whilst this fell short of the target for all vehicles to be delivered within five days, it exceeds the current best case in the industry where capability is 40 days (3DayCar, 1999-2001; Parry and Graves, 2008b). A BTO strategy was shown to be technically feasible. However, the enterprise transformation remains a challenging proposition that contrasts convention and BTO implementation is not straightforward.

In summary, based on our evidence, it can be argued that the (European) automotive industry would need to realize a number of transformative steps to achieve a shift from BTS to BTO strategy. These steps can be summarized as follows:

- Management of product development and configuration for flexible production
- Innovative production, supply and logistics networks to deliver improvement in the flexibility and integration of the supply chain across physical, information, data, planning, and control processes.

- Management of information and material flows to facilitate a seamless knowledge and information stream and to achieve required change in the management of supplies, inventories, packing, transportation and monitoring to meet the demand of BTO operation.
- Establish the extended automotive enterprise such that the supply chain exists within and across firms with a focus placed upon responsiveness to final customer demand.

Summary and Conclusion

Similar to the Lean approach, the implementation of BTO is expected to have a slow start but rapidly gain momentum as investors realize the potential of the strategy. BTO addresses three of the seven wastes within automotive production identified by Taiichi Ohno, namely overproduction, unnecessary transportation and inventory (Ohno, 1988). The BTO approach facilitates the move for automotive firms to become more sustainable, achieving the triple bottom line of economic, environmental and societal prosperity (Elkington, 1994; Stone and Brauer, 2008). This is further enhanced by holistic product development which focuses on production and logistics as well as performance in use. This innovative product development approach may reduce logistics costs by 45% (Seidel and Huth, 2008). The research suggests that the savings made improve upon return on capital employed and potentially increases the attractiveness of automotive firms to investors. Capital investment is critical to new product development. The most critical supplier to a firm is the bank as the source of capital for investment, but the automotive industry's relatively slow clockspeed in comparison to telecommunications and consumer electronics leads to uncertainty with regards possible future returns, making it less attractive for investors (Parry and Graves, 2008).

The BTO environmental impact improves upon current approaches to automotive manufacture as it removes waste by reducing unnecessary transport and halting the production of unwanted vehicles (Ohno, 1988). In the strategy proposed by the ILIPT project vehicles are assembled locally and major modules and components only made to confirmed order BTO by suppliers near final assembly plants. Such local production leads to shorter transportation distances and removes overproduction, lowering the CO₂ emissions of the enterprise.

Societal impacts are more difficult to quantify as data available is sparse. The automotive industry is an integral part of the European economy. Estimates propose that the automotive industry generates €375 billion in tax revenues across Europe and supports 12 million families (ACEA, 2012). The BTO approach requires that the vehicles are manufactured close to the customer, which would mean that this approach would help to maintain the high levels of employment within the major markets, protecting jobs and tax revenues and hence maintaining the benefit to society.

However, adopting new practices is highly complex and likely to be confronted with a variety of obstructions. Much of the complexity and obfuscation is linked to the interactions of institutional push and need pull mechanisms. The adoption of lean production has encouraged entire industries (e.g. automotive, aerospace, construction, health) to transition towards new business models. However, promising practices are too frequently presented as a universal panacea, yet evidence suggests that there is no 'one size fits all' best practice (Leseure et al., 2004). Nevertheless, this paper provides a critical overview for adoption of a BTO strategy within the European Automotive Industry. As stated in the introduction, the implementation of the approach has already begun within parts of the European industry. The adoption of a BTO process within an engine plant has been successful, but represents an internal implementation. This is a low risk and hence low reward implementation as the majority of the dependencies and data flows were internal to the OEM. A broader enterprise adoption requires firms to learn from these internal transformations.

This paper provides a vision for the Build to Order enterprise transformation for automotive production. BTO is presented as a sustainable future strategy for the European automotive industry. A BTO transformation means automotive firms can achieve the triple bottom line of economic, environmental and societal prosperity (Elkington, 1994; Stone and Brauer, 2008). As Ohno noted “an idea does not always evolve in the direction hoped for by its creator” (Ohno, 1988, p.100). Future work will lie within the dynamic of implementation. Implementation of the concepts will uncover new learning and, as with lean, this transformation will be a long and emergent process. Changing global

contexts will change the detail of the approach (Pettigrew, 2012). It is within the changing context that an environment can be developed to initiate the automotive enterprise transformation proposed. The work done has shown that enterprise collaboration can deliver a vehicle to customers within a reasonable timescale but this must be supported by innovative logistics and supplier integration. A BTO transformation strategy offers the industry a unique opportunity to minimize overcapacity and realize the true potential of lean production.

Acknowledgement

We would like to acknowledge the support of the European Commission and ILIPT industry partners who funded the research. In particular we could also like to thank Andreas Untiedt, automotive body expert at ThyssenKrupp AG, for his the time and contributions he made towards the writing of this paper. Finally, we would like to acknowledge the support of Springer publications, in particular Claire Protherough and Anthony Doyle for their continued support.

References

- 3DayCar, (1999-2001). Available online: <http://www.3daycar.com/>
- ACEA, (2012) “The Automotive Industry Pocket Guide”, European Automobile Manufacturers Association. Available online: http://www.acea.be/images/uploads/files/ACEA_POCKET_GUIDE_2012_UPDATED.pdf.
- Automotive News, (2006-9). Available online: <http://www.autonews.com/>
- BBC News, Honda's four-month break begins, (1st February 2009). Available online: <http://news.bbc.co.uk/1/hi/business/7859863.stm>.
- BMW.com. Available online: http://www.bmw.com/com/en/insights/bmw_design_2012/icons/opener.html#row05-2
- Bower, J. L. and Hout, T. M. (1988) Fast-cycle capability for competitive power. Harvard Business Review, 66(6), 110-118.
- Chopra, S. and Meindl, P. (2009) Supply Chain Management – Strategy, Planning and Operation 2nd Edition, Pearson Education.

- Cossin, D. and Schellhorn, H. (2007). Credit risk in a network economy. *Management Science*, 53(10), pp. 1604-17.
- Crumley, B. (2012). Europe's Debt Crisis Seems Bad? Look at Its Car Industry. *Time*, July 30th.
- Elbl-Weiser, K. (2003) Automobile coatings of the future - New solutions for modular automobile designs, BASF Coatings AG.
- Elkington, J. (1994) Towards the sustainable corporation: Win-win-win business strategies for sustainable development. *California Management Review*, 36(2), 90-100.
- Fischer, J.-G., Witthaut, M. and Berger, M. (2008) Functionalities of supporting IT systems: current situation, future requirements and innovative approaches. In Parry, G. and Graves, A. Eds *Build to Order: The Road to the 5-day Car*, Springer Chapter 13, pp 223-237.
- Fine, C. (1999). *Clockspeed: Winning Industry Control in the Age of Temporary Advantage*, Perseus.
- Gneiting, P. and Sommer-Dittrich, T. (2008). An overview of modular car architecture: the OEMs perspective on why and how. In: Glenn C. Parry and Andrew P. Graves, ed's *Build to Order: The Road to the 5-day Car*, Springer Chapter 6, pp 13-34.
- Gude, M. and Hufenback, W. (2008) Modular Concepts and the design of the ModCar body shell. In Glenn C. Parry and Andrew P. Graves, ed's *Build to Order: The Road to the 5-day Car*, Springer Chapter 7, pp 133-153.
- Henderson, B. A. and Larco, J.L. (2000) *Lean Transformation: How to change your business into a lean enterprise*. Oaklea Press.
- Henshaw, M. J. C., Morcos, M. S., Siemieniuch, C. & Sinclair, M. A. (2011) Identification of Induced Complexity in Product Service System Enterprises. *Journal of Enterprise Transformation*, 1(4), 269-289.
- Hofman, E. (2011). Natural hedging as a risk prophylaxis and supplier financing instrument in automotive supply chains. *Supply Chain Management: An International Journal*, 16(2), 128-141.
- Holweg, M. (2008) The Evolution of Competition in the Automotive Industry. In Glenn C. Parry and Andrew P. Graves, ed's *Build to Order: The Road to the 5-day Car*, Springer Chapter 2, pp 13-34.

- Holweg, M. and Miemczyk, J. (2002) Logistics in the 'three-day car' age. Assessing the responsiveness of vehicle distribution logistics in the UK. *International Journal of Physical Distribution & Logistics Management*, 32(10), 829–850.
- Holweg, M. and Miemczyk, J. (2003) Delivering the '3-day car'- the strategic implications for automotive logistics operations. *Journal of Purchasing and Supply Management*, 9(2), 63–71.
- Holweg, M. and Pil, F. K. (2001) Successful Build-to-Order Strategies Start with the Customer. *MIT Sloan Management Review*, 43(1), 74-83.
- Holweg, M. and Pil, F. K. (2004) *The second century: Reconnecting customer and value chain through build-to-order ; moving beyond mass and lean production in the auto industry*, MIT Press.
- Howard, M. and Squire, B. (2007) Modularization and the impact on supply relationships. *International Journal of Operations and Production Management*, 27(11), 1192-1212.
- Ianni, P. (2011) Notes From The Field: Transforming Europe's Second Largest Car Manufacturer: PSA Peugeot Citroën. *Journal of Enterprise Transformation*, 1(4), 263-268.
- ILIPT, 2004-2009, Available: <http://www.ilipt.org/>
- Leseure, M., Birdi, K., Bauer, J., Denyer, D. and Neely, A. (2004) Adoption of promising practice: a systematic review of the evidence, report for AIM [Advanced Institute of Management], (February 2004). Available online: <http://www.aimresearch.org>.
- Liker, J. K. (2004) *The Toyota Way: 14 Management Principles from the world's greatest manufacturer*, McGraw-Hill.
- Lotuscars.com. Available online: <http://www.lotuscars.com/gb/engineering/lightweight-architectures>
- Merlis, S., Sylvester, M. and Newton, A. (2001) Lean manufacturing: the way to a better business model, Dresdner Kleinwort Wasserstein Research: Industry Report, Automotive/Auto Parts: Dresdner Kleinwort Wasserstein.
- Miemczyk, J. and Holweg, M. (2004) Building cars to customer order-what does it mean for inbound logistics operations. *Journal of Business Logistics*, 25(2), 171–197.
- Monden, Y. (1983) *Toyota production system – practical approach to production management*, Industrial Engineering and Management Press.

Nightingale D. (2009). Principles of Enterprise Systems. Second International Symposium on Engineering Systems. MIT, Cambridge, Massachusetts.

Ohno, T. (1988) Toyota Production System, Productivity Press.

Bureau Van Dijk Electronic Publishing. Available at: Osiris database [Accessed: 7th. May 2009].

Ost, S. and Mandel, J. (2008) Modelled Scenario examples for planning and execution processes. In Glenn C. Parry and Andrew P. Graves, ed's Build to Order: The Road to the 5-day Car, Springer Chapter 14, 239-254.

Parasuraman, A., Zeithaml, V.A. and Berry, L.L. (1985). A conceptual model of service quality and its implication, Journal of Marketing, 49(4) 41-50.

Parry, G. C. and Graves, A. P. (2008) Build to Order: The Road to the 5-day Car. Springer.

Parry, G. C. and Roehrich, J. K. (2012). An engineering systems approach to strategic change: the case of the European automotive industry. Strategic Change, 21(5-6), 249-262.

Parolini, C. (1999) The Value Net: A Tool for Competitive Strategy. John Wiley & Sons.

Persson, F. and Olhager, J. (2002) Performance simulation of supply chain designs. International Journal of Production Economics, 77(33), 231-245.

Pettigrew, A. (2012). Context and action in the transformation of the firm: A reprise. Journal of Management Studies, 49(7), 1304-1328

Purchase, V., Parry G., Valerdi R., Nightingale D. and Mills J. (2011) Enterprise Transformation: why are we interested in it and what are the challenges?, Journal of Enterprise Transformation, 1(1), 14–33.

Reuters (2009) UPDATE 2-German May car sales up 40 pct on tax 'steroids', Reuters, (Wednesday Jun 3rd 2009). Available online: <http://www.reuters.com/article/idUSL347499620090603>

Rifkin, S. (2011). Raising questions: How Long Does It Take, How Much Does It Cost, and What Will We Have When We Are Done? What We Do Not Know About Enterprise Transformation. Journal of Enterprise Transformation, 1(1), 34-47.

Roehrich J, Parry G, Graves A. (2011). Innovation in inter-firm networks: the Build-to-Order paradigm. International Journal of Automotive & Technology Management, 11(3), 221–235.

- Rosemain, M. (2012). France agrees to guarantee Peugeot bonds in exchange for influence. Bloomberg News, Detroit Free Press, October 25th. Available Online: Freep.com
- Roth, G. (2011) Sustaining Lean Transformation Through Growth and Positive Organizational Change. *Journal of Enterprise Transformation*, 1(2), 119-146.
- Rouse, W. B. (2011) Necessary Competencies for Transforming an Enterprise. *Journal of Enterprise Transformation*, 1(1), 71-92.
- Ryall, J. (2009) Toyota to halt Japanese production in February and March”, *Telegraph.co.uk*, (Tuesday January 6th 2009). Available online: <http://www.telegraph.co.uk/finance/newsbysector/transport/4139865/Toyota-to-halt-Japanese-production-in-February-and-March.html>
- Sanchez-Ramirez, C., Cedillo-Campos, M.G., Perez-Villanueva, P., Martinez-Flores, J.L. (2011). Global economic crisis and Mexican automotive suppliers: impacts on the labor capital, *Simulation: Transactions of the Society for Modelling and Simulation International*, 87(8) 711–725
- Scavarda, L.F., Schaffer, J., Scavarda, A.J., Reis, A.dC. Schleich, H. (2009) Product variety: an auto industry analysis and a benchmarking study. *Benchmarking: An International Journal*, 16(3), 387-400
- Schaffer, J., Schleich, H. (2008) Complexity Cost Management. In: Glenn C. Parry and Andrew P. Graves, ed's *Build to Order: The Road to the 5-day Car*, Springer Chapter 9, 155-174.
- Seidel, T. and Huth, T. (2008) How the electro-mechanical valve train accelerates logistics and reduces costs. In Glenn C. Parry and Andrew P. Graves, ed's *Build to Order: The Road to the 5-day Car*, Springer Chapter 18, pp 311-322.
- Stalk, G. Jr., (1988) Time – the next source of competitive advantage. *Harvard Business Review*, 66(4), 41-51.
- Stone, G. and Brauer, K. (2008) D7.7.2/D8.7.2 – Assessment of the Socio-economic & environmental impact potential of a European implementation of the 5DayCar, ILIPT report D7.7.2/D8.7.2 for the EU Commission, (April 24th 2008).
- Stone, G., Parry, G. C. and Graves, A. P. (2006) Transformation of the European automotive industry, the future of lean. *International Journal of Financial Transformation*, 18, 10-15.

Thompson, C. (2009) GM, Ford plunge as U.S. sales drop 41.3%. Automotive News Europe, (March 3rd 2009). Available online: [http:// www.autonews.com/article/20090303/ANA05/903039928/1078/COPY01](http://www.autonews.com/article/20090303/ANA05/903039928/1078/COPY01)

Toth, M., Mandel, J., Ost, S. and Dürr, P. (2008) D 8.6.2: Validated Digital Evaluation Platform, ILIPT report D8.6.2 for the EU Commission (April 30th 2008).

Truckenbrodt, A. (2001) Modularized Cars – die Quadratur des Autos. Verkehrswissenschaftliche Tage, Dresden.

Untiedt, A. (2009) Modular Vehicle Design and New Materials for Future Demands”, Environment, Safety and Mobility for 2020: The ILLIPT Project, Autoworld, Brussels (February 2008). Available online: <http://www.clepa.eu/index.php?id=techday2009>.

Waller, B. (2001) “The Customer and the 3DayCar”, Executive Briefing 3DayCar. Available online: <http://www.3daycar.com/>

Watson, T. (2009) “Chrysler Almighty!”, Canadian Business, Vol. 82, Issue 21

Webster, S. A. (2006) Top dealer says there are more unsold cars than reported”, Detroit Free Press (Online), (2006) 26th October.

Williams, G., Waller, B. (2000) “Do customers want instant gratification”, Executive Briefing 3DayCar, Available online: <http://www.3daycar.com/>

Womack, J. P., Jones, D. R. and Roos, D. (1990) The Machine That Changed the World, Rawson Associates.

Womack, J. P. and Jones, D. T. (1996) Lean Thinking: Banish Waste and Create Wealth for Your Corporation, Simon & Schuster.

Tables and Figures

	2007	2008	2009	2010	2011	CAGR% 07-11
BMW	7.37	2.57	1.85	5.99	8.28	3%
Daimler AG	6.13	3.66	-0.88	7.22	7.43	5%
Fiat SPA	6.62	6.27	-0.18	2.39	4.75	-8%
Ford Motor Co	-0.26	-7.28	2.73	6.59	14.88	175%
GM	n.a.	-183.29	132.17	6.29	8.49	n.a.
Honda	7.77	2.1	3.42	6.78	2.71	-23%
Peugeot	4.12	0.66	-1.14	5.09	3.14	-7%
Renault	10.18	3.44	-9.39	11.9	7.37	-8%
Toyota	8.6	-2.11	1.24	2.3	1.62	-34%

Table 1: 5 year Return on Capital Employed for leading global automotive firms
(source data: Bureau Van Dijk Electronic Publishing)

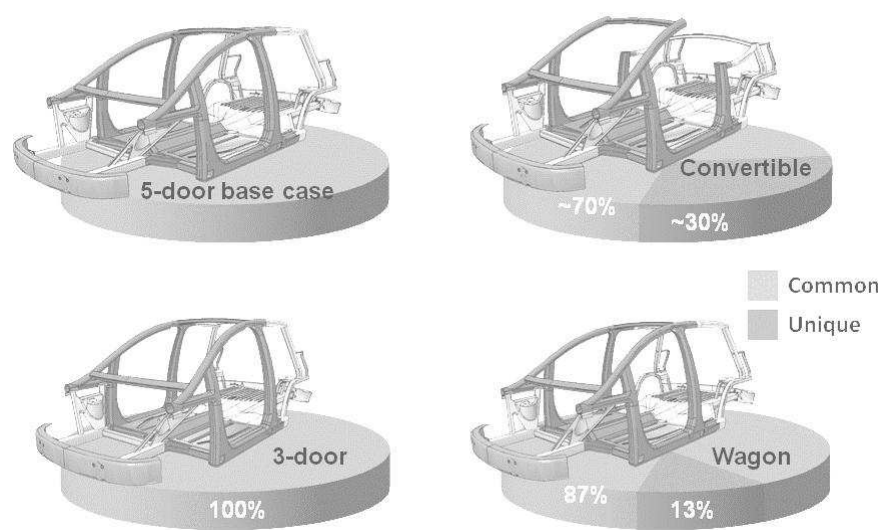


Figure 1 Illustration of commonality between variants (Untiedt, 2009)

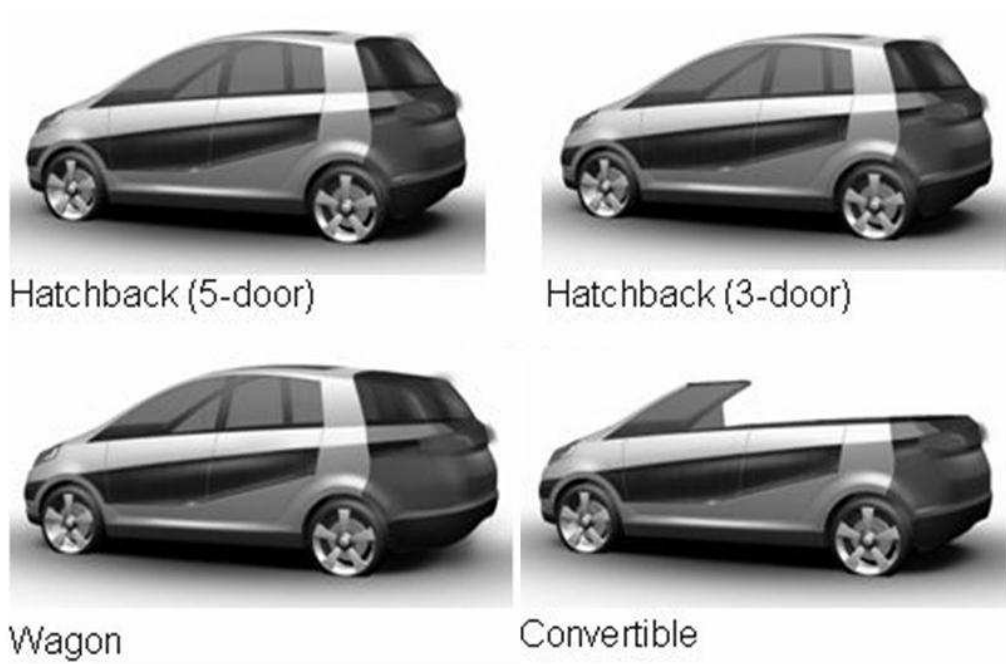


Figure 2 Styling variants of the ModCar (Adapted from Gude and Hufenback, 2008).

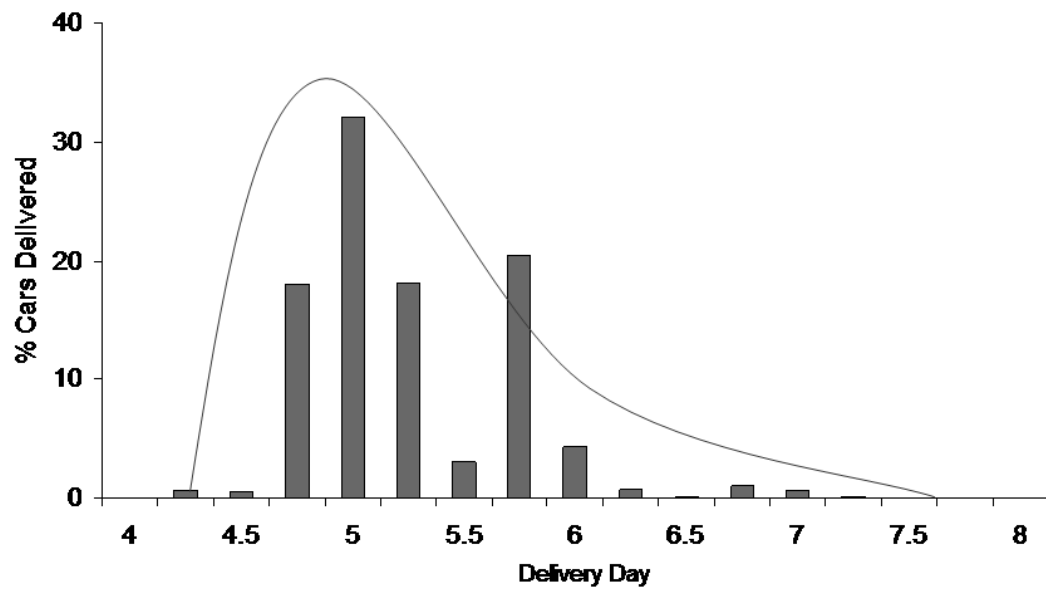


Figure 3 Analysis of Build to Order methodology (Toth et al., 2008)